<sup>71</sup> Small, minor inclined joint—Showing strike and dip

Small minor vertical or near-vertical joint—Showing strike

## CORRELATION OF MAP UNITS

Spruce Pine Plutonic Suite

Ashe Metamorphic Suite

Zac metaconglomerate Zakq kyanite gneiss m pegmatite and metasomatic schist aluminous schist

## INTRODUCTION

The Celo 7.5-minute quadrangle lies in Yancey, McDowell, and Mitchell counties, western North Carolina. Within the quadrangle are the small communities of Celo, Hamrick, and Busick. The Blue Ridge Parkway and N.C. Highway 80 are the major transportation corridors on the quadrangle. The major water features are the South Toe River and Big Crabtree Creek. Total elevation relief is 4,397 feet with a low of 1,930 feet on Armstrong Creek at the eastern quadrangle boundary and a high of 6,327 feet at Čelo Knob. The Blue Ridge escarpment, the rugged transition zone between the Blue Ridge and Piedmont physiographic provinces, transects the southeastern portion of the quadrangle. The Eastern Continental Divide corresponds to the top of the escarpment in this region. Portions of the quadrangle were mapped previously by Brobst (1962) and Howell (1975).

## **GEOLOGIC OVERVIEW**

Bedrock of the Celo quadrangle is entirely within the Fries/Spruce Pine thrust sheet of the eastern Blue Ridge portion of the Tugaloo terrane (Trupe, 1997; Hatcher and others, 2007).

The Fries/Spruce Pine thrust sheet contains Neoproterozoic metasedimentary and mafic rocks of the Ashe Metamorphic Suite (AMS). These rocks are thick sequences of complexly deformed and metamorphosed clastic sediments deposited in marine rift basins. Interspersed with these sediments are lesser amounts of mafic volcanic rocks and ultramafic rocks thought to have originated as oceanic crust at a spreading center (Misra and Conte, 1991; Raymond and Abbott, 1997). These metasedimentary lithologies were complexly deformed and metamorphosed to amphibolite facies conditions during Taconic orogenesis. Amphibolite facies metamorphism associated with Acadian/ NeoAcadian orogenesis overprints older fabrics (Johnson and others, 2001). The distribution of map units and metamorphic foliations define a complicated fold interference pattern interpreted to be the result of Taconic and NeoAcadian deformation, and igneous intrusion of the Spruce Pine Plutonic Suite.

Numerous Silurian to Devonian-aged granodioritic bodies and pegmatites of the Spruce Pine Plutonic Suite intrude the AMS (NCGS unpub. data, 2022; Brobst, 1962; Kish, 1983, 1989). These bodies are typically concordant with, but locally cross-cut metamorphic foliation on the quadrangle. Xenoliths of foliated metasedimentary rocks are locally present within the bodies. Metasedimentary lithologies near pegmatites are commonly more micaceous and coarse-grained than those where pegmatites are absent.

## DESCRIPTION OF MAP UNITS<sup>1</sup>

82°15'0"W

35°52'30"N

### **WESTERN TUGALOO TERRANE**

apatite, epidote group minerals, thulite, pyrite, chalcopyrite, and pyrrhotite.

**Spruce Pine Plutonic Suite** Granodiorite — White to very light-gray, mottled; non-foliated to weakly foliated; coarse-grained; equigranular to inequigranular; granoblastic. Bodies are lenticular to tabular. Thickness of bodies ranges from decimeters to kilometers.

Consists of plagioclase feldspar, quartz, potassium feldspar, and muscovite. Accessory minerals include biotite, garnet,

Pegmatite — White to very light-gray, mottled; non-foliated to weakly foliated; very coarse-grained; equigranular to inequigranular; granoblastic. Bodies are lenticular to tabular. Thickness of bodies ranges from decimeters to tens of meters. Pegmatite occurs as sill-like or cross-cutting bodies within the Ashe Metamorphic Suite. Mineralogically similar to Spruce Pine granodiorite (Swanson and Veal, 2010). Consists of plagioclase feldspar, quartz, potassium feldspar, and muscovite. Accessory minerals vary greatly upon locality and include biotite, garnet, apatite, epidote group minerals, pyrite, chalcopyrite, pyrrhotite, beryl, samarskite, columbite, autunite, and torbernite. A zircon crystallization age of ca. 367.6 +/- 3.5 Ma (pending further refinement) was obtained for NCGS sample NB70, a pegmatite body within

#### **Ashe Metamorphic Suite**

the Zapm unit.

Undivided — Heterogeneous unit consisting of interlayered layers and lenses of laterally and vertically grading sedimentary and mafic volcanic rocks metamorphosed to kyanite and sillimanite grade. Rock types include schist, Za schistose metagraywacke, metagraywacke, conglomeratic metagraywacke, metaconglomerate, metasandstone, amphibolite, and minor calc-silicate. Thickness of layering ranges from centimeters to meters. Where possible Za was mapped and subdivided based on dominant rock type. Detrital zircon analyses were performed on NCGS sample BC290, a metasandstone outcrop within the Za unit. A large majority of the zircon population are Mesoproterozoic in age. The three youngest detrital grains are ca. 589, 592, and 605 Ma.

**Dunite** — Grayish-yellow-green; fine- to medium-grained, forsterite, with minor enstatite and bronzite, and disseminated chromite; when altered, serpentine minerals, anthophyllite, talc, and vermiculite replace olivine as disseminated grains, and in interior veins and peripheral areas.

Amphibolite — Dark-green to black; fine- to coarse-grained; weakly to strongly foliated; equigranular; granoblastic to nematoblastic; consists of hornblende, plagioclase feldspar, epidote group minerals, quartz, garnet, chlorite, relict pyroxene, titanite, magnetite, and opaque minerals. Interlayered with other Ashe Metamorphic Suite lithologies and locally intruded by pegmatite. Can occur as a minor rock type throughout the other map units, where it may represent a metamorphosed volcanic rock.

Metaconglomerate — Medium-light-gray to medium-dark-gray; coarse-grained (most commonly granule size, but with some pebble size); inequigranular; granoblastic; non-foliated to weakly foliated; variable thickness; granules are dominantly quartz; commonly interlayered with metagraywacke, schistose metagraywacke, and mica-schist.

Zakg Kyanite gneiss — Highly altered and heterogeneous unit characterized by an abundance of kyanite and/or muscovite porphyroblasts. Typical rock is mottled light-gray to brown; coarse-grained; foliated; inequigranular to equigranular; porphyroblastic; locally migmatitic; consists of biotite, plagioclase, quartz, muscovite, kyanite and/or sillimanite, garnet, and minor accessory and trace minerals; kyanite porphyroblasts up to 15 cm; felsic interlayers may be due to metasomatism or migmatization; interlayered with other Za lithologies.

Pegmatite and metasomatic schist — Heterogeneous mix of pegmatite, granodiorite, metasomatic schist, and other Ashe Metamorphic Suite lithologies. Pegmatite bodies range in size from sub-meter to decameter and are typically concordant with surrounding metasediments. Pegmatite is white to light gray to light pink; coarse-grained; granoblastic; consists of plagioclase feldspar, quartz, potassium feldspar, muscovite, biotite, and minor amounts of opaque minerals, and garnet. Metasomatic schist is dark gray; medium- to coarse-grained; well foliated; inequigranular; lepidoblastic; consists of muscovite, biotite, quartz, plagioclase feldspar, potassium feldspar, garnet, and minor accessory minerals.

**Tagr Graphitic schist** — Dark-gray to greenish-gray to medium-gray; fine- to medium-grained; well foliated to mylonitic; quigranular to inequigranular; lepidoblastic to porphyroblastic; consists of muscovite, biotite, garnet, sericite, quartz, graphite, feldspar, chlorite, pyrite, and accessory minerals; interlayered with lesser amounts of metaarkose,

Zas Aluminous schist — Very-light-gray to greenish-gray to medium-gray; strongly foliated; fine- to medium-grained; equigranular to inequigranular; lepidoblastic to porphyroblastic; consists of muscovite, biotite, quartz, feldspar, garnet, kyanite, and sillimanite; thickness of layering varies; commonly interlayered with schistose metagraywacke. <sup>1</sup>Mineral abundances are listed in decreasing order of abundance based upon visual estimates of hand samples and thin-sections.

## WHOLE ROCK ICP ANALYSIS¹ OF SELECTED SAMPLES

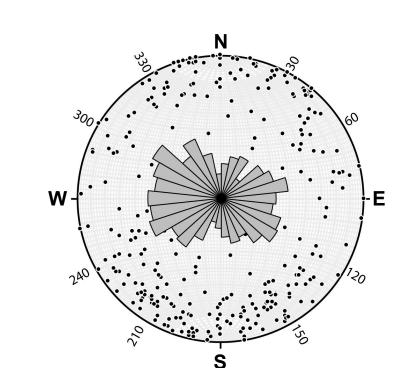
<sup>1</sup>Whole Rock Inductively Coupled Plasma - Atomic Emission/Mass Spectrometer analysis conducted by Bureau Veritas, 9050 Shaughnessy St, Vancouver, BC Canada V6P 6E5. Sample numbers correspond to thin section and whole rock sample localities shown on geologic map

State Plane Coordinate System LOI = loss on ignition in percent SUM = Sum total in percent

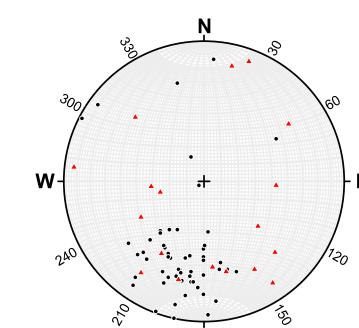
PPM = parts per million. Ni analyzed by Bureau Veritas LF200 and AQ200 procedures.

## **SCHMIDT EQUAL AREA STEREONET DATA**

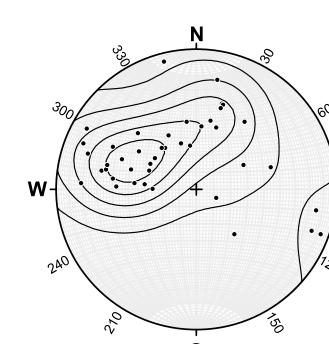
Stereonets created using Stereonet 10 and R Statistical Software (Allmendinger, et al., 2012; Cardozo and Allmendinger, 2013; Agostinelli and Lund, 2022)



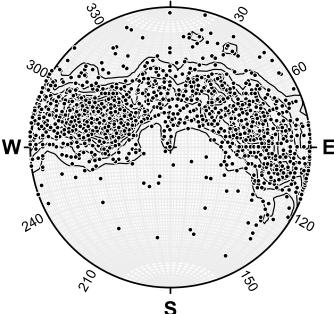
Contoured poles to joints with unidirectional rose diagram. Azimuthal bin size = 12 degrees. Joint count 300.



Bearing and plunge of fold hinges in black and mineral lineations in red. Fold hinge count 55. Mineral lineation count 18.



Poles to mylonitic foliation. Mylonitic foliation count 42.



Contoured poles to foliation. Foliation count 1485.

# **REFERENCES**

Agostinelli, C. and Lund, U., 2022, R package 'circular': Circular Statistics (version 0.4-95), URL https://r-forge.r-project.org/projects/circular/

Allmendinger, R.W., Cardozo, N., and Fisher, D., 2012, Structural geology algorithms: Vectors and tensors in structural geology; Cambridge University Press.

Brobst, D.A., 1962, Geology of the Spruce Pine district, Avery, Mitchell and Yancey counties, North Carolina, U.S. Geological Survey Bulletin 1122-A, map scale 1:24,000. Cardozo, N., and Allmendinger, R.W., 2013, Spherical Projections with OSXStereonet: Computers & Geosciences, v. 51, p. 193-205, doi:10.1016/j.cageo.2012.07.021.

Hatcher, R.D., Jr., Bream, B.R., and Merschat, A.J., 2007, Tectonic map of the southern and central Appalachians: A tale of three orogens and a complete Wilson cycle, in Hatcher, R.D., Jr., Carlson, M.P., McBride, J.H., and Martínez Catalán, J.R., eds., 4-D Framework of Continental

Crust: Geological Society of America Memoir 200, p. 595–632, doi: 10.1130/2007.1200(29). Johnson, B.S., Miller, B., and Stewart, K., 2001, The nature and timing of Acadian deformation in the southern Appalachian Blue Ridge constrained by the Spruce Pine Plutonic Suite, western North Carolina: Geological Society of America Abstracts with Program, v. 33, p. A30.

Kish, S.A., 1983, A geochronological study of deformation and metamorphism in the Blue Ridge and Piedmont of the Carolinas: Ph.D. Dissertation, University of North Carolina, Chapel Hill, 220p.

Kish, S.A., 1989, Paleozoic thermal history of the Blue Ridge in southwestern North Carolina - constraints based on mineral cooling ages and the ages of intrusive rocks: Geological Society of America Abstracts with Program, v. 21, p. 45.

Howell, D.E., 1975, Geology of the southern two-thirds of the Celo 7.5 minute quadrangle, North Carolina, M.S. thesis, University of North Carolina – Chapel Hill, 60p. Misra, K.C. and Conte, J.A., 1991, Amphibolites of the Ashe and Alligator Back Formations, North Carolina: Geological Society of America Bulletin, v. 103, p. 737-750.

Raymond, L.A. and Abbott, R.N., 1997, Petrology and tectonic significance of ultramafic rocks near the Grandfather Mountain Window in the Blue Ridge of Western North Carolina, Carolina Geological Society Field Trip Guidebook, p. 67-85.

Gradational Contact

Swanson, S.E. and Veal, W., 2010, Mineralogy and petrogenesis of pegmatites in the Spruce Pine District, North Carolina, USA. Journal of Geosciences. 55. 10.3190/jgeosci.062.

Trupe, C.H., 1997, Deformation and metamorphism in part of the Blue Ridge thrust complex, northwestern North Carolina. [Ph.D. thesis], Chapel Hill, NC: The University of North Carolina.

3000

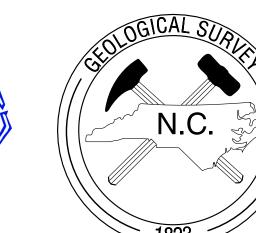
2500

2000

#### 82°7'30"W ROAD CLASSIFICATION Produced by the United States Geological Survey North American Datum of 1983 (NAD83) Local Connector \_\_\_\_\_ World Geodetic System of 1984 (WGS84). Projection and 1 000-meter grid: Universal Transverse Mercator, Zone 17 Local Road 10 000-foot ticks: North Carolina Coordinate System of 1983 This map is not a legal document. Boundaries may be S Route generalized for this map scale. Private lands within government QUADRANGLE LOCATION reservations may not be shown. Obtain permission before FS Passenger Route entering private lands. UTM GRID AND 2016 MAGNETIC NORT DECLINATION AT CENTER OF SHEET CONTOUR INTERVAL 40 FEET Check with local Forest Service unit U.S. National Grid 1 2 3 2 Micaville NORTH AMERICAN VERTICAL DATUM OF 1988 for current travel conditions and restrictions. 3 Spruce Pine with limited Forest Service updates, 2012 - 2016 4 Mount Mitchell 5 Little Switzerland 6 Montreat This map was produced to conform with the ...National Hydrography Dataset, 2014 National Geospatial Program US Topo Product Standard, 2011. A metadata file associated with this product is draft version 0.6.19 .....National Elevation Dataset, 2008 CELO, NC 6 7 8 7 Old Fort Boundaries......Multiple sources; see metadata file 1972 - 2016 8 Marion Wes Wetlands......FWS National Wetlands Inventory 1977 - 2014 4500 3500 3000 2500

This geologic map was funded in part by the USGS National Cooperative Geologic Mapping Program.





Unit Contact interpretive patterns of subsurface foliation orientations based upon surficial structural measurements

> Research supported by the U.S. Geological Survey, National Cooperative Geologic Mapping Program under STATEMAP (award number G21AC10805, 2021) The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U.S.

Bedrock Geologic Map of the Celo 7.5-minute Quadrangle, Yancey, McDowell, and Mitchell Counties, North Carolina

Bart L. Cattanach, G. Nicholas Bozdog, Sierra J. Isard, and Matthew Tibbits Geology mapped from August 2021 to October 2022. Location of some pegmatite and granodiorite bodies from Brobst, 1962. Map preparation, digital cartography and editing by G. Nicholas Bozdog, Sierra J. Isard, Bart L. Cattanach, and Joshua R. Benton

This is an Open-File Map. It has been reviewed internally for conformity with North Carolina Geological Survey mapping standards and with the North American Stratigraphic Code. Further revisions or corrections to this Open File map may occur. Some station data omitted from map to improve readability. Please contact the North Carolina Geological Survey for complete observation and thin-section data.

## **EXPLANATION OF MAP SYMBOLS**

CONTACTS Zone of Confidence: 300m 

Gradational contact—Identity and existence certain, Contact—Identity and existence certain, location location inferred

PLANAR FEATURES (For multiple observations at one locality, symbols are joined at the "tail" ends of the strike lines) Inclined metamorphic or tectonic foliation—Showing

Small, minor inclined joint, for multiple observations Inclined metamorphic or tectonic foliation, for multiple observations at one locality—Showing strike and dip at one locality—Showing strike and dip Small, minor vertical or near-vertical joint, for multiple Vertical metamorphic or tectonic foliation—Showing strike observations at one locality—Showing strike

Inclined mylonitic foliation, for multiple observations Inclined mylonitic foliation—Showing strike and dip at one locality—Showing strike and dip

Inclined bedding, for multiple observations Small, minor inclined fault—Showing strike and dip at one locality—Showing strike and dip

LINEAR FEATURES

Inclined aligned-mineral lineation—Showing bearing and plunge ■ <sup>18</sup> Inclined slickenline, groove, or striation on fault

surface—Showing bearing and plunge

 $_{\pi}^{56}$  Inclined fold hinge of generic (type or orientation unspecified) small, minor fold—Showing bearing and plunge

Inclined crenulation lineation—Showing bearing and plunge

OTHER FEATURES

 Float station Thin section and whole rock analysis sample location

Vertical metamorphic or tectonic foliation, for multiple

observations at one locality—Showing strike

strike and dip

Open pit, quarry, or glory hole X Prospect (pit or small open cut) Abandoned sand, gravel, clay, or placer pit

Destroyed adit or tunnel entrance Abandoned open pit, quarry, or glory hole

Abandoned adit or tunnel entrance

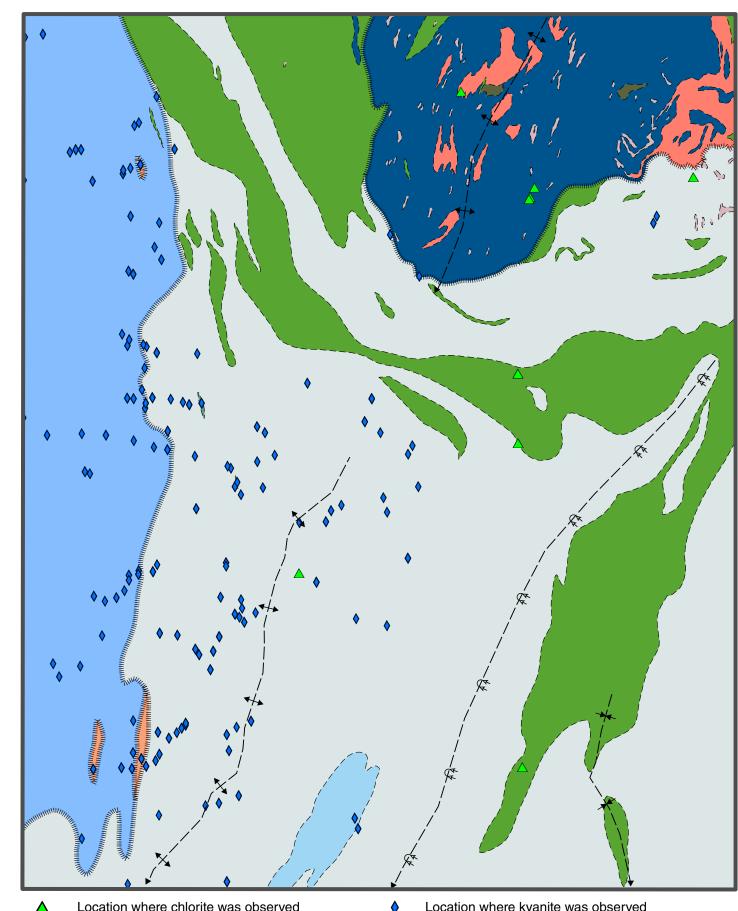
Inclined mine shaft

Sand, gravel, clay or placer pit

## NATURAL RESOURCES

MIC - Mica SDG - Sand and gravel FLD - Feldspar

## **TECTONIC MAP**



△ Location where chlorite was observed Location where kyanite was observed ■ Arrow—Shows plunge direction of fold Overturned synform—Identity and existence certain, \_\_\_\_\_\_\_\_ Antiform—Identity and existence certain, — 🕁 — location approximate. Beds on one limb are overturned; location approximate arrows show dip direction of limbs

Synform—Identity and existence certain, location approximate

> TRAVERSE MAP Hillshade derived from a six meter pixel resolution LiDAR (Light Detecting And Ranging) digital elevation model. Red lines show paths of field traverses.

